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Applied Logistics Research

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NOTICE

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THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

FOR THE COMMANDER

//SIGNED//

DANIEL R. WALKER, Colonel, USAF
Chief, Warfighter Readiness Research Division
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14. ABSTRACT

The Applied Logistics Research program was initiated by the Air Force Research Laboratory's Logistics Readiness Branch (AFRL/HEAL) to provide specialized research support to develop, demonstrate, and evaluate logistics technologies. Within the scope of this program specific research tasks could be focused on feasibility studies, cost benefit analyses, modeling and simulation data and algorithms, front-end analyses, field test support activities, and demonstration system development within the domains of operational, contingency, and acquisition logistics. Operational logistics emphasizes improving the performance of logistics personnel in all operational environments. Contingency logistics encompasses technologies to improve the speed, efficiency and ease of deployment of all logistics support elements necessary to support contingency operations. Acquisition logistics focuses on improving the logistics elements of systems during development through improved system design support and information technologies.

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1. Introduction

The Applied Logistics Research program was initiated by the Air Force Research Laboratory's Logistics Readiness Branch (AFRL/HEAL) to provide specialized research support to develop, demonstrate, and evaluate logistics technologies. Within the scope of this program specific research tasks could be focused on feasibility studies, cost benefit analyses, modeling and simulation data and algorithms, front-end analyses, field test support activities, and demonstration system development within the domains of operational, contingency, and acquisition logistics. Operational logistics emphasizes improving the performance of logistics personnel in all operational environments. Contingency logistics encompasses technologies to improve the speed, efficiency and ease of deployment of all logistics support elements necessary to support contingency operations. Acquisition logistics focuses on improving the logistics elements of systems during development through improved system design support and information technologies.

After reviewing a wide range of logistics challenges and research requirements, and assessing budget and schedule constraints, AFRL/HEAL decided to narrow the actual research tasks to the seven areas of interest listed below. The corresponding University of Arkansas project identifier for each research area is referenced in parenthesis.

- Task 1 (MM0206) - Quantifying the Impact of Aircraft Cannibalization [4]
- Task 2 (PMD0204) - The Use of Decision Models in the Development of a Collaborative Integrated Solutions System [5]
- Task 3 (MM0202) - Fleet-Level Selective Maintenance and Aircraft Scheduling [6]
- Task 4 (BSIT0204) - Multi-Mission Selective Maintenance Decisions [7]
- Task 5 (MM0205) - Quantifying the Effect of Commercial Transportation Practices in Military Supply Chains [8]

- Task 6 (BSIT0201) - Hybrid Simulation/Analytic Models for Military Supply Chain Performance Analysis [9]

- Task 7 (ATA0201) - Commercial Practices as Applied to Total Asset Visibility [10]

Tasks covering each of the areas above were developed and consolidated into a single delivery order on the AFRL Technology for Readiness and Sustainment (TRS) research contract with Northrop Grumman Information Technology Inc. The tasks on the delivery order were performed over a 24 month period by the University of Arkansas, Department of Industrial Engineering, with the assistance of Northrop Grumman. This report provides a condensed summary of the research and findings for each task. Further discussion and details of the research conducted for each task can be found in the individual technical reports submitted as a separate deliverable for each delivery order.

2. Task 1 - Quantifying the Impact of Aircraft Cannibalization

Fleet aircraft maintenance involves a variety of activities that are intended to maximize the readiness of the fleet while adhering to budgetary constraints. One such activity is cannibalization. Because of the military's focus on fleet readiness and the expense of maintaining large spare parts inventories, all military services rely extensively on cannibalization and consider it to be a normal part of fleet maintenance. A recent five-year study identified approximately 850,000 documented U.S. Air Force (USAF) and Navy (USN) cannibalizations, which consumed 5.3 million maintenance hours. Due to the lack of available spare parts and unpredictable lead times from depot to base, aircraft are intentionally cannibalized to return "hangar queens" (aircraft temporarily designated as cannibalization or donor aircraft) to service and maintain an acceptable level of aircraft readiness.

The primary objective of this research task was to develop a mathematical modeling methodology for assessing the impact of cannibalization on fleet performance in order to identify

policies for making effective cannibalization decisions, and to study the impact of these policies on the management of spare parts in the supply chain. To achieve this objective, two research avenues were pursued in parallel. The first avenue involved the development and analysis of a "generic" cannibalization model. This discrete-event simulation model was used to investigate two key issues related to aircraft readiness - cannibalization and spare parts inventory levels. The results of this investigation indicated that cannibalization can solve fleet readiness problems, but conversely, these same results also support the contention that additional investment in spare part inventories can provide the same readiness benefits without the additional labor requirements required by cannibalization. The second avenue involved the development and analysis of two discrete-event simulation models based upon the cannibalization policies and practices at Hill AFB, UT. These models were used to investigate several key issues raised by USAF officers experienced with conditions similar to those existing at Hill AFB. The results of this analysis showed that:

- Consolidating cannibalization actions using a cannibalization (CANN) dock is superior to maintaining a CANN bird at each AMU.
- The appropriate number of CANN-dock aircraft for Hill AFB is two.
- Reducing the CANN bird duration at Hill AFB to 30 days should increase average aircraft readiness.

3. Task 2 - The Use of Decision Models in the Development of a Collaborative Integrated Solutions System

AFRL/HEAL identified a need to have a strategically aligned performance measurement system for flightline maintenance activities that could account for the entire flightline maintenance process in order to improve aircraft scheduling and the achievement of mission objectives. The primary research activities undertaken as part of this project included:

- Identification of a strategically aligned, performance measurement system and research into the system's development and implementation process.
- Investigation of current USAF flightline maintenance processes.
- Production of associated development guidelines.
- Validation of these guidelines through a case study application.
- Investigation of software implementations.

The review of the performance measurement literature resulted in the selection of the Kaplan and Norton Balanced Scorecard (BSC) as the appropriate measurement system for the flightline maintenance process. Kaplan and Norton introduced the BSC in the early 1990s in an attempt to reconcile problems in traditional management strategies that overemphasize financial measures at the expense of progress and growth [1]. The BSC performance management system allows organizations to clarify their strategy and assure that every aspect of operations is directed toward the success of these goals (Balanced Scorecard Basics, 2003). When considering important measures all at once, as suggested by the BSC, management can detect whether one area is improving at the expense of another area (Kaplan and Norton, 1996).

The scope of the research project focused on the USAF flightline maintenance process. This process encompasses the inspection and servicing of aircraft that takes place from the time an aircraft lands through all the activities necessary to recover the aircraft and prepare it to successfully complete another mission. Thorough knowledge of this process was acquired to determine relevant performance measures, understand why specific measures behave as they do, and to gain insight into reasons why these measures fall outside acceptable parameters.

The BSC development process is one that requires thorough knowledge about internal operating procedures and a comprehensive understanding of the system being studied. It was

determined that detailed guidelines specified in the Kaplan and Norton BSC methodology would be valuable in supporting the development of a BSC for flightline maintenance in a typical USAF Aircraft Maintenance Unit (AMU). Hence, a case study was developed and undertaken to validate and exemplify the steps in the BSC Development Guide, and to support the development of a preliminary BSC for flightline maintenance activities accomplished within an AMU. The resulting BSC for flightline maintenance consists of the following four perspectives and measures:

- Mission Perspective
    - Maintenance hours per flying hour
    - Mission-Capable (MC) rate
    - Partially Mission-Capable Maintenance (PMCM)
    - Sorties flown
    - Totally Not Mission-Capable Maintenance (TNMCM)
- Influencing Factors Perspective
    - Cannibalization (CANN) rate
    - Mission-Impaired Capability Awaiting Parts (MICAP) fill rates
    - Maintenance Scheduling Effectiveness
    - Totally Not Mission-Capable Supply (TNMCS)
- Management Perspective
    - Adherence to Operations (OPS)/Maintenance Squadron (MXS) schedule
    - Deferred Discrepancies (DD) rate Awaiting Maintenance (AWM)
    - Total maintenance deviations
    - 4-hour fix rate

    - 8-hour fix rate
    - 12-hour fix rate
    - Days in Phase/Isochronal Inspection (ISO)
- Internal Enhancement Perspective
    - Cannot Duplicate (CND) rate
    - Repeat-Recur (RR) rate
    - Special Experience Identifiers
    - Total abort rate
    - Training schedule adherence
    - Upgrade Training
    - Unit average technical skill level

An anonymous questionnaire was developed to elicit the expertise of logistics personnel in ranking the criticality of the measures on the preliminary BSC. The results indicated that the "mission perspective" is the most critical, followed by "management perspective" and "influencing factors perspective" respectively. Respondents indicated that the least critical was the "internal enhancement perspective".

Within the "mission perspective", MC rate is the most critical measure and PMCM is the least critical. The MICAP fill rate is ranked as the most critical measure within the "influencing factors perspective". Within the "management perspective", the adherence to aircraft operations and maintenance schedules is the most critical measure, and the least critical measures are DD rate, AWM, and the 4-hour fix rate. The CND rate, RR rate, upgrade training, and unit average technical skill level are the most critical measures within the "internal enhancement perspective".

In addition to the development of a preliminary BCS for USAF flightline maintenance, it was determined that a review of existing BSC software packages would benefit future implementation of a BSC. Hence, a review of the three most prominent BSC software packages was conducted based upon industry standards for such packages. These packages included *ActiveStrategy Enterprise*™, *SPImpact*™, and *pbviews*™. The packages were reviewed to assess their adherence to relevant industry standards. The relevant features evaluated included network compatibility, ease of setup and use, and user friendliness. It was observed that *pbviews*™ provided the best support for all preferred features.

4. Task 3 - Fleet-Level Selective Maintenance and Aircraft Scheduling

Military organizations rely on the effective and efficient use of weapon systems to accomplish their respective missions. In many cases, these organizations rely on combinations of identical systems (aircraft) to accomplish specific missions (e.g. four F-16C aircraft to fly a close air support mission). However, in some cases, the number of maintenance resources (people, support equipment, etc.) are insufficient to support the type and number of aircraft platforms needed in a specified timeframe to meet mission requirements. Therefore, a maintenance manager must decide how to best allocate available resources. The allocation of resources falls within the domain of selective maintenance. Selective maintenance is defined as the process of identifying the subset of maintenance activities to perform from a set of desired maintenance actions. Although the modeling of repairable equipment has been studied extensively, traditional studies tend to focus on a single system and ignore the mission profile of the system. For the Air Force, these limitations prevent current models from providing meaningful guidance relative to maintenance planning and sortie scheduling.

This research project investigated the use of a mathematical modeling methodology for integrating and assessing maintenance planning and mission (operations) scheduling issues. A literature review was conducted of policies, procedures, and models associated with selective aircraft maintenance and mission scheduling in both military and commercial domains. The review indicated that 1) a majority of the selective maintenance literature was limited in that current models only consider a single system; and 2) that most of the fleet assignment literature is motivated by the commercial airline industry, which focuses on meeting Federal Aviation Administration (FAA) maintenance requirements.

Following the literature review, background research was performed to define the extensions or enhancements necessary for a current selective maintenance model to incorporate combinations or "sets of systems", versus just an individual system. A scenario was developed to support the background research, and in particular, the definition of a selective maintenance model that could support both the assignment of multiple aircraft to respective missions, and the execution of missions based on the constraint that maintenance is performed only between missions.

Originally, the scenario requirements evaluated during the background research were mathematically assessed using a total solution enumeration strategy. Although the enumeration strategy guarantees an optimal solution, scenarios involving more than four aircraft resulted in lengthy computational times; therefore, a model based on a genetic algorithm (GA) was developed to solve larger scenarios. The background research and the development of the GA provided key insights used in the formulation and specification of solution procedures for both the static and dynamic optimization models that integrate aircraft assignment and selective maintenance.

In addition to the GA model developed as part of the background research, a mathematical optimization model was developed to integrate aircraft assignment (given a relatively static mission profile) and selective maintenance decision-making. The optimization model considers upcoming missions that are not identical and defines a parameter to quantify the "difficulty" of each upcoming mission. A solution procedure was developed for performing this optimization as well as to support a study of the behavior of the model using numerical examples. Because of the complexity of the optimization model, we utilized a GA to perform the required optimization.

In the final portion of the research project, a more complex optimization model was formulated to address dynamic mission profiles. In this case, dynamic mission profiles include missions that start and end at different times, and where maintenance and scheduling decisions are made at specific time intervals. We again utilized GAs to perform the required optimization.

5. Task 4 - Multi-Mission Selective Maintenance Decisions

This project builds upon the body of knowledge in selective maintenance. Selective maintenance falls within the domain of maintenance modeling and optimization. The use of mathematical modeling for the purpose of modeling repairable systems and designing optimal maintenance policies for these systems has received an extensive amount of attention in the literature [2, 3]. The primary objective of this research was to develop a modeling-based methodology for managing selective maintenance decisions when the planning horizon extends beyond a single future mission. Achieving this objective, required the completion of four key research activities including: 1) extending existing selective maintenance models into a multi-mission formulation, including the extension of scenario parameters such that decision variables prescribed for one mission become the input parameters for a subsequent mission; 2) defining an

objective function that maximizes the expected number of successful missions over the planning horizon; 3) formulating a stochastic dynamic programming model to solve the multi-mission scenario and using an enumerative approach to determine optimal selective maintenance decisions; and 4) developing and demonstrating these techniques using a multi-mission, selective maintenance scenario.

To solve this particular scenario, a customized Microsoft Excel application was developed. The inputs to the model include the following:

- m – number of subsystems
- n_i – number of components in subsystem i
- r_i – reliability of a functioning type i component
- s – number of limited maintenance resources
- α_{il} – amount of resource l required to repair a type i component
- β_l – the amount of resource l available during each maintenance break

Visual Basic code within the Excel spreadsheet enumerates all possible combinations of failed components, $\underline{a}$. For each $\underline{a} \in \Phi$, the code generations a solution (i.e., the $\underline{d}$'s). If the solution is infeasible, it is disregarded. However if a feasible solution is generated, the expected value of the number of successful missions with t missions remaining, $W(t,\underline{a})$, is tabulated. If the value of $W(t,\underline{a})$ is equal to or greater than the largest previously computed value, that solution (and the corresponding value of the expected number of successful missions) is written to a file, and a new solution is generated. After generating all possible solutions for each mission in the scenario, the optimal solutions are output to an Excel worksheet. This enumeration code is able to handle any scenario size and guarantees the identification of optimal solutions. Also, solution feasibility checks and computations are done "on-the-fly" eliminating the excessive use of

computer memory. The numerical example showed that selective maintenance decisions relative to a multi-mission scenario may differ from decisions generated for a single-mission scenario.

6. Task 5 - Quantifying the Effect of Commercial Transportation Practices in Military Supply Chains

Military supply chains encompass a complicated network of suppliers and customers who deal with a wide variety of items. These items can range from complete weapon systems and associated reparable items, to non-reparable consumables such as jet fuel. With respect to the Air Force, demands inside a supply chain network (particularly for reparable items) typically originate at the unit or base level and are aggregated upward to the service depot level. The service depots in-turn, are supplied by either military wholesalers, such as the Defense Logistics Agency, or directly from commercial vendors. These numerous layers of the supply chain often result in unnecessary costs and delay times, as well as low network reliability. Better integration between multiple levels of the supply chain may be achieved through the effective use of different transportation modes and criterion. However, traditional multi-echelon inventory and readiness-based models applicable to military logistics networks have not fully investigated the ability of effective transportation use to reduce cost, delay times, and improve overall system readiness.

In this research project, a simulation-based methodology was developed for quantifying the effect of transportation options (that is, truckload shipping, less-than-truckload shipping, transshipments, and express air shipping) on shipping costs, customer wait times, abort rates, and operational availability. A simulation model was developed based upon the Air Force's Multi-Indenture Multi-Echelon (MIME) repairable parts system. This simulation model encompasses a structure that includes 24 individual shop replaceable units (SRUs) composing six line replaceable units (LRUs), 432 aircraft, six bases, and one depot.

Experiments were designed and conducted to provide insight into the more significant factors impacting weapon system operational availability, abort rates, customer (maintenance personnel) wait time, and total transportation cost. Eleven factors were selected as independent variables for the experiments. These factors included: commercial shipping (less than full or full shipment loads), sortie duration, sortie frequency, MICAP (item priority), repair time, inventory position, item failure time, pre-flight and post-flight aircraft maintenance, unscheduled maintenance, local repair, and lateral transshipments (shipment of items between bases). The impact of each factor, along with its respective interaction with other factors, was assessed against each of the four indicators of model performance identified above.

In the first series of experiments, a fractional, factorial experimental design was used. With this design, there were 128 individual design points, each of which was replicated five times, yielding a total of 640 simulation runs. The information provided by these simulation runs allows the creation of linear response surface regression models for each response. The regression models provided the ability to evaluate the effect of each factor on each response.

A second set of experiments was completed in an attempt to find the most appealing combination of factors. For each design point, the four response values were scaled between zero and one, weighted by importance, and added together to yield a utility value. The utility value provides a mechanism to compare the 128 design points. From the 128 design points, the top nine were chosen based upon utility, and a second set of 65 replications was run for each of the nine. The second set of experiments provided statistical information on the best performing combination of factors based upon utility. The findings from the experiments indicated the following:

- Mission Impaired Capability Awaiting Parts (MICAP), Time to Failure (TTF), Local Repair, Shipping Option, Sortie Duration, and Inventory Position were the most influential factors in affecting the values of Operational Availability, Abort Rate, Customer Wait Time, and Total Transportation Cost.
- Reliance on MICAP overshadows the other transportation cost components.
- Reliance on MICAP hides many problems within the supply chain.
- A combination of altering the amount of repair resources allocated to the base level and the amount of inventory at the base level provides an opportunity for improving system performance.
- Different shipping strategies (such as Less than Truck Load [LTL], Truck Load [TL], and Emergency Lateral Transshipment [ELT] can induce significant system improvement and warrant future study.

This research provided significant insights into the operation of commercial logistics within the Air Force MIME supply chain.

7. Task 6 - Hybrid Simulation/Analytic Models for Military Supply Chain Performance Analysis

This research project extends the knowledge base concerning logistics network modeling and design. As part of this effort, basic research techniques were developed to support the modeling of logistical networks within a hybrid simulation/analytic framework. The first step in this process was to develop robust approximations for portions of large-scale simulation models. To this end, the novel idea of utilizing neural networks as a meta-modeling technique to replace specific aspects of a simulation was explored, starting with the replacement of queuing stations within a logistics network. Any logistics network can be formulated as a network of material flowing through processes requiring resources. Under this research project, a new methodology

utilizing neural networks was developed for forming approximations and developing improved "approximators" for queuing stations within a logistics network. Neural networks were developed and demonstrated to close the gap between the output of Whitt's GI/G/m approximation and the results obtained via simulations was of a GI/G/m queue. Once the neural network was trained, the input parameters and resulting output of Whitt's GI/G/m approximation, along with additional information describing the arrival and service distributions of the queue, were fed to the neural networks to yield an acceptably accurate approximation for the expected wait time in a GI/G/m queue. These approximations can be embedded in parametric decomposition algorithms to assess the logistics network as a whole. The motivation for developing this approximation was the integration of such an approximation in hybrid simulation/analytic methods for evaluating logistic networks. The neural network approximation developed easily beats Whitt's approximation for correlated arrivals, but further investigation is required to assure a robust approximation. Future work should investigate the performance of these approximations within the larger logistical network context.

8. Task 7 - Commercial Practices as Applied to Total Asset Visibility

"Asset blindness" occurred in Operations Desert Shield and Desert Storm. Over the course of these two conflicts, over 40,000 military containers were shipped to the Middle East. More than 20,000 of these containers had to be opened, inventoried, resealed, and reinserted into the transportation system, because military personnel on the receiving end did not know the contents of the containers or their final consignees. At the conclusion of the conflict, there were more than 8,000 containers and 250,000 Air Force pallets that were unopened and their contents still a mystery. General Robert H. Scales, in his book, *Certain Victory: The U.S. Army in the Gulf War*, details many of the logistical deficiencies realized by the U.S. military during the

"build-up" of forces for Operation Desert Shield, particularly the tracking the location of shipping contents and determining their contents.

The concept of Joint Total Asset Visibility (JTAV) is intended to address some of the logistics shortfalls and deficiencies highlighted during the Gulf War. JTAV is the ability to provide users with timely and accurate information on the location, movement, status, and identity of units, personnel, equipment, and supplies. JTAV also seeks to utilize the aforementioned information to improve the Department of Defense's logistic practices. The JTAV concept encompasses three asset categories: "in storage," "in transit," and "in process." These categories enable JTAV to determine the location, movement, status, identity of units, personnel, equipment, and supplies in the overall supply chain.

The purpose of this research project was to further examine the military's objective for the JTAV 2020 program, as well as review current supply chain policies and practices of the Air Force. A specific focus of the research was to identify potential areas of improvement and makes recommendations as to how specific areas of the supply chain might be enhanced by current commercial practices and technology regarding asset visibility.

Extensive research has been reported in the fields of Automatic Identification (Auto-ID) and Radio Frequency Identification (RFID), along with other current commercial practices and technology involving asset visibility. RFID technology, combined with an effective database system, will give the Air Force complete visibility into its supply chain including the ability to locate materiel anywhere in the world in real time.

The main focus of JTAV is an integrated data environment. The concept of JTAV is based extensively on the capability to collect data from various databases ("feeder systems") that

track and store information on the three types of assets discussed above. The data from these systems must then be processed and "fused" into useful information, and presented in a form that is easy to understand for the user. The primary challenge in accomplishing this task is the tremendous number of databases that exist and attempting to link all of them together. Each of the databases represents a small portion of visibility for a particular category, function, or agency within the DOD. Joint Vision 2010 attempts to create a system architecture that allows a "single point of entry" into the many dimensions of TAV.

In order for RFID to be implemented, all materiel must be tagged. This is best accomplished by the manufacturer, in the production stage, so that the tag is internal and protected from damage and tampering. The Air Force will need to embark upon a program that gets manufacturers of Air Force products to tag their parts and products in the manufacturing stage. This will be a difficult task since tagging parts will require retooling, and in some cases, redesign of the part itself. All parts of assemblies and aggregates must be tagged. For example, if Lockheed Martin delivers an F-16 to the Air Force, every part of the F-16 must be tagged. Of course, tagging only needs to be done with parts requiring tracking (e.g. line replaceable units or assemblies), and not for piece part components such as bolts, screws, washers, etc.

The implementation of an RFID "tagging" program in the Air Force should take a phased approach, beginning at the pallet or container level and progress downward to tagging at the case level, and eventually to the tagging of specific items. Item tagging will offer the most benefit to the Air Force, but of course is the most difficult to implement. Implementation of tagging in phases will allow the Air Force to gradually adjust to automatic identification and RFID technology. This will also greatly reduce the number of readers that initially need to be installed in the Air Force supply chain infrastructure.

The two main questions related to the application of RFID are whether to implement active or passive technology, and frequency selection. Due to the high variability of environments and conditions in which RFID tags will be read, it is recommended that the Air Force use multi-band readers. The Air Force has assets on the water, in the desert, in the air, and in warehouses. These environments will necessitate a versatile reader capable of operating in all of these environments. Following the recommendations of the Auto-ID center, the reader should have capabilities of reading both high frequency (HF) (13.56 MHz) and ultra high frequency (915 MHz) frequency bands. Each band will provide benefits for specific applications and it important to have the versatility to switch between the two. High frequency bands are less expensive than inductive low frequency tags and are generally passive in nature. They have a short read range and are best suited for applications that do not require multiple tag reads. This is also currently the most widely available frequency worldwide.

Ultra high frequency tags, when purchased in high volumes, can be cost effective over low frequency and even high frequency tags. Their high performance and range are well-suited for multiple tag reading applications. Ultra high frequency is for use with active or passive tags, but better performance comes with active tag applications. The draw back to this frequency is that Japan does not allow transmission on this frequency band.

Both active and passive technologies have their place within the Air Force supply chain. Based on this research, the following recommendations are made for the potential application of active and passive RFID technologies in the Air Force:

- Active RFID, although more costly than passive RFID, should be used for area monitoring applications such as obtaining real-time inventory information in a warehouse,

monitoring the location of empty and loaded air cargo containers, and monitoring the security of stored containers.

- Active RFID should be used in spot-level locating applications such as determining the exact parking location of aircraft, locating the specific storage rack of a pallet or container within a distribution center, or identifying the specific loading bay in current use.

- Anytime multiple tags need to be read such as multiple pallets, containers, or objects moving through a port, active RFID should be used.

- Whenever security or tampering is an issue for materiel located within a container, active RFID should be implemented to create electronic seals. For higher-level security items, active RFID should be used to log the time that a seal was tampered with.

- Passive RFID should be used for locating specific objects in a small area such that the surrounding areas are not also scanned. Passive RFID operating at 13.56 MHz would work best, also eliminating unwanted "cross reads" that can occur with higher frequencies.

- Passive RFID can also be used on low-level security items where it is only necessary to determine if a container has been opened, and no further information is required.

- Electronic manifests (at the container level) will be very important in deployment situations. With an electronic manifest, detailing every element of materiel inside, the contents can automatically be updated and checked into a database. Only active RFID offers electronic manifest capabilities built into the tag.

- Constraints exist when using radio frequency technology in the presence of munitions. For this reason, it is recommended that global positioning satellite (GPS) tags be used to track munitions. Not only does this eliminate radio waves around explosive ordinates, it also provides constant, real-time tracking of munitions anywhere in the world. This is especially

useful given the importance of extra security precautions needed in storing and transporting munitions.

Wal-Mart is always on the forefront of emerging technology and maintains a dominant position in its market. Hence, it has the ability to enforce any implementations it wishes to impose. In June of 2003 Wal-Mart set the date of January 2005 for RFID implementation (Murphy and Hayes 2003). This means that 100 key suppliers will have to work with Wal-Mart using RFID to track pallets of goods throughout its supply chain. With this deadline in place there are still many issues to consider, primarily the shortcomings of the current technology and the cost of purchasing RFID tags and readers. The Air Force, like Wal-Mart has considerable influence in the market place to make these kinds of demands on its suppliers.

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